Lecture Module - Error and Uncertainty

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module ? - Error and Uncertainty

Module ? - **Error and Uncertainty**

- Topic 1 - Accuracy and Error
- Topic 2 - Errors, Residuals, and Uncertainty
- Topic 3 - Repeatability and Testing

Topic 1 - Accuracy and Error

- Accuracy and Error
- Estimating Error
- Uncertainty Interval
- GPS Activity

Accuracy and Error

The exact value of a variable is called the _____ _____. The value of the variables as indicated by a measurement system is called the _____ _____. The _____of a measurement refers to the closeness of agreement between the measured value and the true value. But the _____ _____is rarely known _____, and various influences, called _____, have an effect on both of these values. So the concept of the _____of a measurement is a _____one.

Accuracy and Error

Estimating Error

The _____ _____can be estimated but cannot be known _____. In practice a _____value is used in place of the true value. We will discuss this again the the *Calibration Module*.

An estimate of error based using this value is sometimes referred to as _____ _____.

Estimating Error

Uncertainty Interval

"The _____is a numerical estimate of the possible range of the error in a measurement. In any measurement, the _____is not known exactly since the true value is rarely known exactly. But based on available information, the operator might feel confident that the error is within certain bounds, a plus or minus range of the indicated reading. This is the assigned _____."

We will discuss this again the the *Uncertainty Module*.

Text: Theory and Design of Mech. Meas.

Uncertainty Interval

GPS Activity

Experiment: We are going to collect data with the sensor suite on our phones.

Sensor:

- GPS - concept graphic
- info from manufacturer

Logger Apps:

- sensorlogger (Android) - Kelvin Choi
- Sensor Logger (OSX) -Choi Tsz Hei

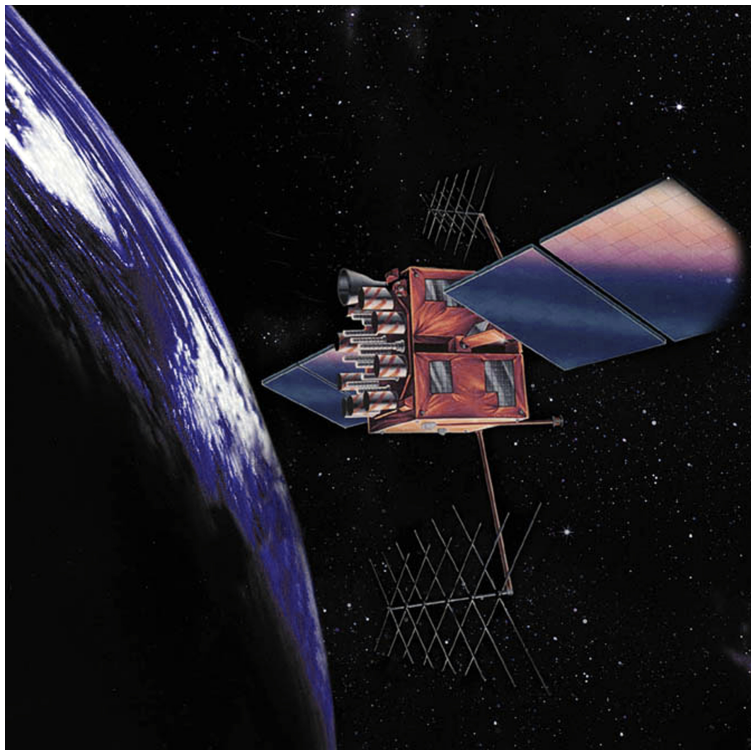


Image:Wikipedia

GPS Activity

Part 1 - Informed Prediction: Generate data you expect the GPS in your phone to report. Show 5 data points on the graph to the right or in a separate figure. Suggestions for making predictions include using a map, map software/website, or some other location measurement system which reports latitude and longitude. Label the axis and scales used.

i	lat_i	lon_i
1		
2		
3		
4		
5		

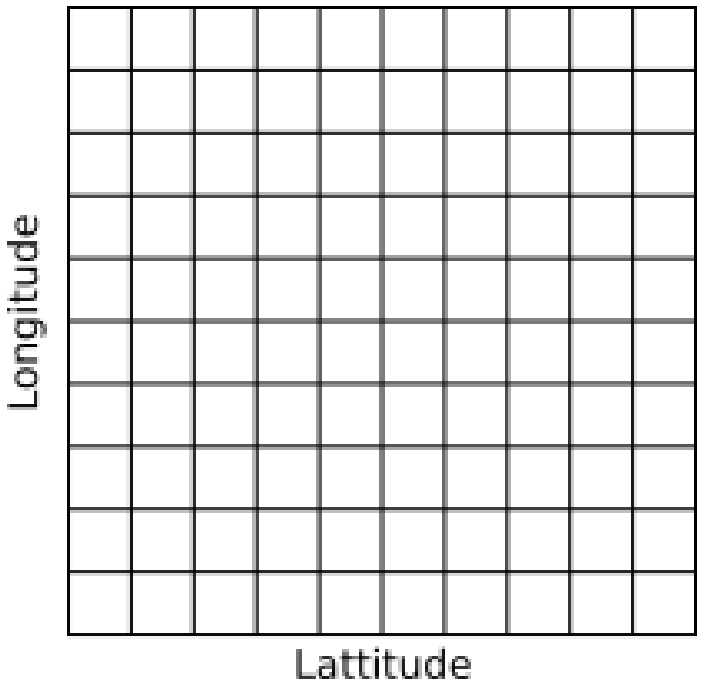


Image: thill

GPS Activity

Part 2 - Measurement: Record GPS from your phone or preffered GPS system. Show 10 or more data points on the graph to the right or in a separate figure. The data can be exported from Sensor Logger into a .CSV file and loaded into MATLAB, Excel, or other software. An example MATLAB program to load and view the data is provided.

i	lat_i	lon_i
1		
2		
3		
4		
5		
6		
7		
8		
8		
9		
10		

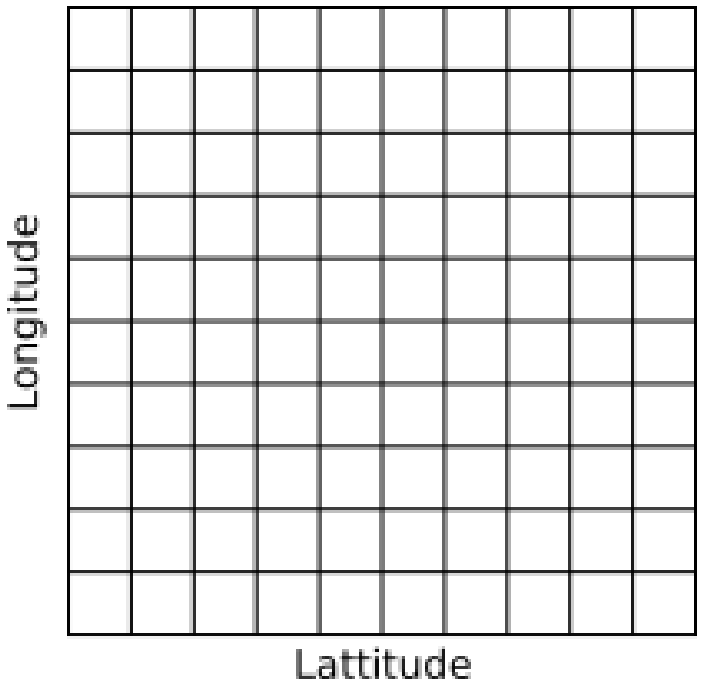


Image: thill

GPS Activity

Part 3 - Analysis/Results/Conclusions: Compare and contrast the predicted and measured sets of data, and answer the following questions about the predictions and measured data.

- Were the predictions reasonable?
- What type of error is present in the measured data? Justify the answer.
- What should be used as a reference to calculate error for this data?

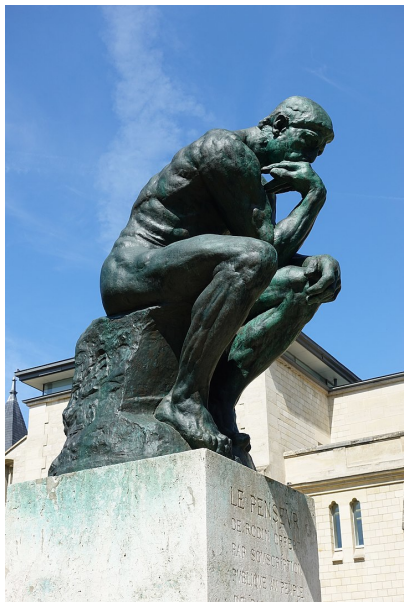


Image: wikipedia Image: wikipedia

GPS Activity

Deliverables:

- Dataset files (.csv) - record acceleration, location, etc.
  - control set (fixed position) - include 'control' in filename
  - activity set 1 - include activity label in filename
  - activity set 2 - include activity label in filename
- Answers to all discussion questions
- MATLAB code generated during activity (.m)
- Figures generated during activity (.png, .jpg)

Topic 2 - Errors, Residuals, and Uncertainty

- Random and Systematic Errors
- Dart Board Example
- Types of Errors
- Sample Uncertainty Data

Random and Systematic Errors

"Errors are effects that cause a measured value to differ from its true value. _____error causes a _____variation in measured values found during repeated measurements of a variable.

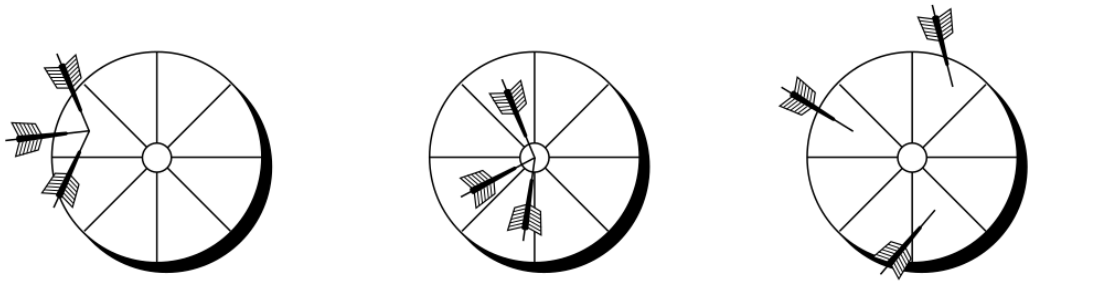
_____error causes an offset between the mean value of the data set and its true value. Both _____and _____errors affect a system's accuracy."

Text: Theory and Design of Mech. Meas.

Random and Systematic Errors

Dart Board Example

"The concept of accuracy and the effects of _____and _____errors in instruments and measurement systems can be illustrated by the throw of darts."



(a) High repeatability gives low random error but no direct indication of accuracy.

(b) High accuracy means low random and systematic errors.

(c) Systematic and random errors lead to poor accuracy.

The ability of a measurement system to indicate the same value on repeated but independent application of the same input provides a measure of the instrument _____."

Text, Image: Theory and Design of Mech. Meas.

Types of Errors

Common categories of errors in measurements are shown below. This is not an exhaustive list.

- Linearity Error, $y_L(x) = a_0 + a_1 x$, $u_L(x) = y(x) - y_L(x)$

  $\%u_{Lmax} = \frac{u_{Lmax}}{r_o} \times 100$
- Sensitivity
- Zero (offset) Error
- Hysteresis Error, $u_h = y_{upscale} - y_{downscale}$, $\%u_{hmax} = \frac{u_{hmax}}{r_o} \times 100$
- Overall Instrument Error

  $$u_c = \sqrt{u_1^2 + u_2^2 + ... + u_M^2}$$

Types of Errors

Types of Errors

Types of Errors

Sample Uncertainty Data

Table 1.1 Manufacturer's Specifications: Typical Pressure Transducer

Operation	
Input range	0–1000 cm H_2O
Excitation	±15 V DC
Output range	0–5 V
Performance	
Linearity error	±0.5% FSO
Hysteresis error	Less than ±0.15% FSO
Sensitivity error	±0.25% of reading
Thermal sensitivity error	±0.02%/°C of reading
Thermal zero drift	±0.02%/°C FSO
Temperature range	0–50 °C

FSO, full-scale operating range.

Text, Image, Data: Theory and Design of Mech. Meas.

Sample Uncertainty Data

Topic 3 - Repeatability and Testing

- Instrument Repeatability
- Conditions for Repeatability
- Reproducibility and Instrument Uncertainty
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Instrument Repeatability

"The ability of a measurement system to indicate the same value on repeated but independent application of the same input provides a measure of the instrument repeatability. Specific claims of repeatability are based on multiple calibration tests (replication) performed within a given lab on the particular unit."

$$\%u_{R_{max}} = \frac{2s_x}{r_0} \times 100$$

Text: Theory and Design of Mech. Meas.

Instrument Repeatability

Conditions for Repeatability

The following conditions need to be fulfilled in the establishment of repeatability:

- the same experimental tools
- the same observer
- the same measuring instrument, used under the same conditions
- the same location
- repetition over a short period of time.
- same objectives

Text: Wikipedia(NIST)

Reproducibility and Instrument Uncertainty

"The term reproducibility, when reported in instrument specifications, refers to the closeness of agreement in results obtained from duplicate tests carried out under similar conditions of measurement ...

... The term instrument precision, when reported in instrument specifications, refers to a random uncertainty based on the results of separate repeatability tests."

Text: Theory and Design of Mech. Meas.

Reproducibility and Instrument Uncertainty